THE LASER CANE

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During the past 30 years, at least 30 attempts have been made to build a useful mobility aid for the blind cane traveler (1,2). All these efforts have resulted in only three aids showing sufficient promise to warrant serious evaluation: the Kay Binaural Sensory Aid (3,4), the Lindsay Russell Pathsounder (5), and the Bionic Laser Cane. Why has the Laser Cane project been relatively more successful than so many of the others? The generalized answer to this question might help in guidance of future research in prosthetics and sensory aids — and a short history of this project may suggest an answer.

In 1945 Lawrence Cranberg (6), then a physicist at the Signal Corps Electronics Laboratory, developed a single-channel optical ranging device to be used by the blind as an obstacle detector. It was quite ingeniously designed and well constructed, judged by the standards of the 1940's. In 1948 RCA built 25 of these "Signal Corps Devices" for the Veterans Administration, who then asked Thomas A. Benham, an outstanding blind physicist and engineer on the faculty of Haverford College, to evaluate them. His evaluation report (7), made in 1952, indicated that the instrument showed promise, but before it could even be looked at more critically, several important changes had to be made.

As a result of this report, the Veterans Administration in 1953 requested Haverford College to have Professor Benham oversee the modifications required to carry out his recommendations. Haverford College, in turn, subcontracted the detail work to what is now Bionic Instruments. Thus began a long, slow, often frustrating journey, which, 10 devices and 16 years later, culminated in the first practical Laser Cane for the Blind.

The basic design criteria for an obstacle detector established by Professor Benham in 1952 have been adhered to throughout the years and have proved sound. Paraphrased, they are:

The device

1. must detect obstables and down-curbs;
2. must be silent and unobtrusive except when giving warning;

3. must be simple to use—the user should not have to "get dressed up" in it; and
4. should perform range measurement on the principle of optical triangulation used in the Signal Corps Device.

The output of the device
5. should be tactile, if possible; and
6. if auditory, should not block other aural cues.

In 1953 transistors had not yet become readily available, so for the first few years miniature vacuum tubes had to be used, together with a few special transistors obtained directly from the laboratories that were developing them. A similar situation prevailed with regard to nickel-cadmium batteries. In addition, no practical light source except the incandescent lamp was commercially available. Thus the first few years were spent developing light sources, getting special low-noise, high-sensitivity photodetectors (first special photomultipliers, then semiconductors), and developing unusual high-efficiency electronic circuitry, typically with the generous aid of the manufacturers.

By 1962 the fifth device (the Model G-5), shown in Figure 1, had been completed and was ready for preliminary "evaluation," solely as an obstacle detector because there seemed no feasible supplement for the long cane in detection of down-curbs. In 1963 twelve G-5's were available for evaluation by the Tracor Co. Two important lessons were learned from this evaluation:

1. Though the G-5 performed adequately according to design, it did not give enough useful information to warrant the nuisance of carrying it, particularly since a cane also had to be carried in the user's other hand to detect down-curbs.

2. Not enough was known about the details of a blind traveler's strategies and performance to attempt a meaningful "evaluation" of any mobility aid except at the most elementary level.

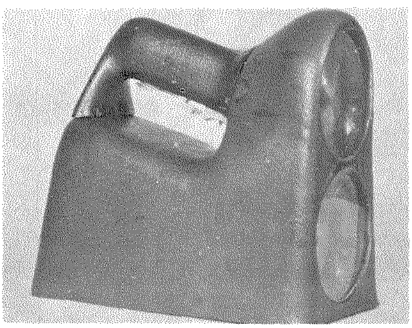


FIGURE 1.—The G-5 Obstacle Detector.

Nineteen hundred sixty-four marked the beginning of the second decade of development. Lasers had recently appeared; the efficient nickel-cadmium battery was becoming available; transistors were workaday devices, and the first solid-state light-emitting diode was soon to become available commercially. An electronic mobility aid appeared to be an idea that could be realized. Working with these remarkable new electronic devices as they took form in laboratories across the country and often before they were commercially available, we developed three prototypes of the cane we hoped would one day prove useful. (Models C-2, C-3, and C-4 are shown in Fig. 2.)

This was an exciting period for us. We had by this time acquired a feel for the range of needs of many blind travelers and for the required "state-of-the-art" that was now rapidly making it possible to meet those needs. In our attempts to establish this optimum set of design criteria we showed one "flashlight" and four successive cane models to approximately 15 institutions, 100 blind people, and perhaps 50 Orientation and Mobility Trainers for test and comment (8).

By 1971 it was judged that the Laser Cane was ready to be tried for a long period by a few seasoned cane users. An evaluation plan was developed by the National Research Council. In August of 1971 eight experienced veterans were "refreshed" and evaluated with long canes, then trained for a month at Hines and Palo Alto Veterans Administra-

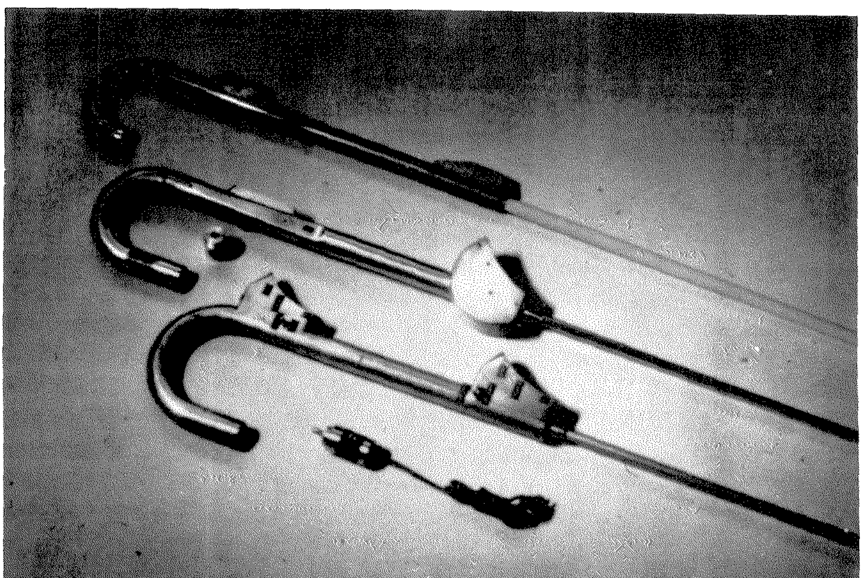


FIGURE 2.—Early models of the electronic cane. In ascending order: C-2, C-3, C-4.

tion Blind Rehabilitation Centers, and finally sent home with their laser canes. They were followed-up and systematically evaluated. A year later seven were still using their canes instead of any other travel aid (except a sighted companion), even though there was no definite statistical evidence of improved mobility in these expert travelers. Following this the Veterans Administration ordered 35 more canes so that a more significant study could be performed.

Upon receipt of this order, engineers at Bionic Instruments, Inc., once again redesigned the cane, tested a prototype with approximately 35 blind travelers, and in March 1974 delivered the 35 C-5 Laser Canes.

By now, one who has managed to read through the above historical summary may see why the project has met with a measure of success. We believe it to be for one important reason:

> We tried to learn what the blind traveler really needed; and we sought to design around *this* set of specifications rather than to build what *we* thought he needed, or what technology suggested might be possible.

This was only possible because the Veterans Administration gave us enough time to go through the process outlined above. Other workers with short periods of support were not able to do this. They took a nonclinical approach. They were intrigued by the technical possibilities inherent in some physical principle, built a device based on this principle, and then found it to be unacceptable as a practical device.

Figure 3 shows the current laser cane, model C-5, which has evolved from our Research and Development Program. Figure 4 shows the C-5 laser cane being demonstrated by one of the skilled and dedicated orientation and mobility specialists, Lee Farmer, of the Hines Veterans Administration Blind Rehabilitation Center.

The C-5 Laser Cane emits pulses of infrared light which, if reflected from an object in front of it, are detected by a photodiode placed behind a receiving lens. The angle made by the diffuse reflected ray passing through the receiving lens is an indication of the distance to the object detected. This principle of optical triangulation was chosen in preference to an ultrasonic approach because of its simplicity and small beamwidth.

The Cane's output for the downward channel emits a 200-Hz tone to notify the user of dropoffs larger than 6 in. which appear approximately two paces (6 ft.) in front of the traveler. Some of the most serious of these would be downward flights of stairs, the edges of station platforms, and open manholes and cellar-ways. Down curbs, though more shallow, can also usually be detected. Proper use of the cane as a long cane, of course, provides further protection.

The straight-ahead beam, about 2 ft. above the ground, can range out to maximum distances of 5 ft. or 12 ft. from the Cane tip to a light-

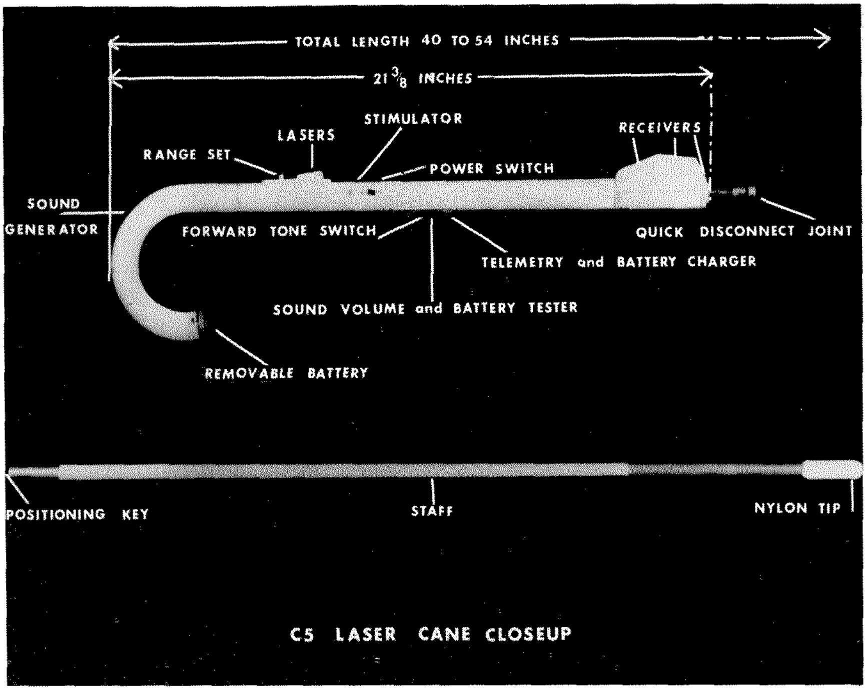


FIGURE 3.—C-5 Laser Cane.

colored target. The operating range is set by the user, who flips a switch located above the laser housing. Any obstacle detected within the selected range will actuate a stimulator that contacts the index finger when the Cane is carried in the usual long-cane manner. In addition, a 1600-Hz tone may also be switched on, if desired; e.g., when a glove is worn in cold weather.

The upward-looking beam will detect obstacles at head height appearing 1½ ft. to 2 ft. beyond the Cane tip. In preliminary studies, it was determined that earlier warnings were confusing, while this distance gave time enough to evade tree branches, signs, and awnings which the conventional long-cane traveler normally has no way of detecting. Obstacle detection is signaled by a high-pitched (2600-Hz) "beep" (see Fig. 5).

Each of the three beams is only 1 in. wide at 10 ft. so objects may be located and measured widthwise with considerable precision by suitable "fine" scanning. The normal, "course" scanning procedure is to sweep the Cane back and forth in an arc, using a modified conventional long-cane technique.

Three GaAs room-temperature injection lasers emit 0.2 microsecond pulses of 9,050 A light 40 times per second. Outputs from three receiv-

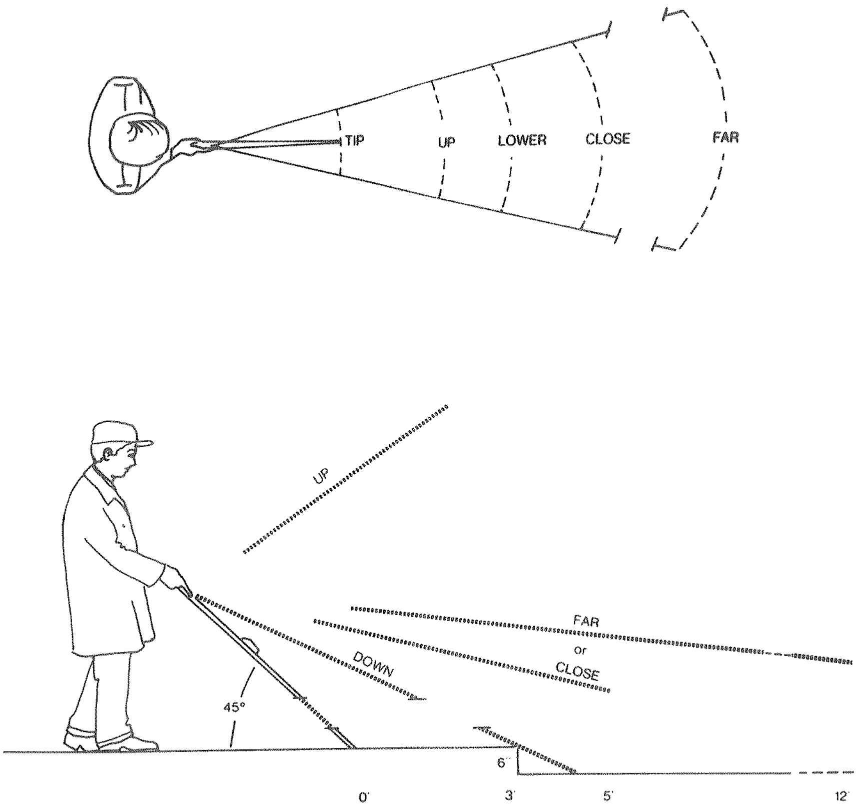
FIGURE 4.—The C-5 Laser Cane in use.

ing silicon photodiodes are each separately amplified, filtered, and coherently gated to eliminate spurious responses due to light from the sun, another Cane, or any other ambient light source, and then are used to operate the appropriate tone generator and/or stimulator. Average power consumed is 600 milliwatts from a 6-volt NiCd rechargeable battery, which operates the Cane for about 3 hours of continuous use on one charge.

Special attention has been paid to keeping the weight low (1 lb.) and to distributing it so that the Cane will approximate the "feel" of a conventional long cane. The battery, for example, is in the crook of the cane.

Five independent laboratories (9) concerned with the safety of laser radiation have studied the emissions from the three GaAs solid-state lasers used in the Cane. Two of these laboratories irradiated the eyes of rhesus monkeys for 30 minutes and for 20 seconds, respectively, with no observable effects. The other three laboratories measured laser power and calculated expected effects. All findings indicated that the Cane was nonhazardous.

More detailed technical descriptions of the C-5 Cane can be found in the literature (10, 11).



PROTECTION ZONES OF C5 CANE

FIGURE 5.—Protection zones of the C-5 Laser Cane.

Bionic Instruments is presently manufacturing 50 C-5 Canes to be delivered to the Veterans Administration early in 1975. These Canes will be distributed to a population of blinded-veteran cane travelers for continued evaluation. Bionic Instruments is also establishing a program to distribute a limited number of Canes to selected blind members of the civilian population. Persons selected will be carefully trained by accredited professional mobility instructors and followed-up over a significant period of time to determine what types of blind travelers can satisfactorily use the Laser Cane as their major travel aid.

Efforts are being made to interest the Lions and other service clubs and organizations in the financial support of the project. Since the C-5 Laser Cane is expected to cost about one-half as much as a dog guide, the Cane most likely will have to be subsidized in a similar fashion. (In production the Cane currently costs approximately $1,950. It costs between $2,900 and $4,500 to train a dog guide and its user.)

In summary, the Laser Cane Project has progressed to the stage of limited production. Technically, the Cane itself is now considered satisfactory. Current efforts are being directed toward:

1. identifying the travelers who can best use the Cane;
2. developing a program for training Orientation and Mobility Instructors; and
3. establishing proper funding channels.

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